The Vertebrate Circulatory System

Transportation
  Respiratory
    Erythrocytes (red blood cells) transport oxygen from lungs to tissues
    Hemoglobin of red blood cells is transporter
    CO₂ is released by cells into blood - carried back to lungs
  Nutritive
    Nutrients enter blood through wall of intestine
    Carried to liver and to all body cells
  Excretory
    Metabolic wastes carried to kidney for removal
    Filtered through capillaries - Excreted in urine
**Regulation**

Hormone transport
- Hormones produced in endocrine glands - transported to target tissues throughout body

Temperature regulation
- Warm-blooded vertebrates are homeotherms
- Heat distributed by circulating blood
- Temperature adjusted by directing flow to or from extremities

**Protection**

Blood clotting
- Protects against blood loss when vessels are damaged
- Involves proteins in plasma and platelets

Immune defense
- Leukocytes, white blood cells, provide immunity against disease agents
- Are phagocytic, produce antibodies or have other actions
**Blood Vessels**

Arteries - carry blood away from heart

Arterioles - network of microscopic vessels of arterial tree

Capillaries - fine network of thin-walled tubes

Venules - small vessels that collect blood from capillaries

Veins - return blood to heart

Arteries, arterioles, veins and venules have similar structure:
- four layers of tissue
  - endothelium, elastic fibers, smooth muscle, connective tissue
- too thick to permit exchange of materials with surrounding tissues

Exchange with tissues occurs in capillaries, endothelium is only layer
- molecules and ions leave blood plasma by filtration (pressurized)
- travel through pores in capillary walls or transported through endothelial cells
**Arteries and Arterioles**

Elastic fibers allow large arteries to expand and recoil when receiving blood from the heart - helps to buffer the effect of pulsing on capillary beds. Smaller arteries and arterioles are less elastic but have thicker smooth muscle, allowing change in diameter. Small diameter arteries and arterioles cause greatest resistance to blood flow.

**Vasoconstriction** - through contraction of smooth muscle increases resistance, decreases flow volume.

**Vasodilation** - through relaxation of smooth muscle decreases resistance, increases flow volume.
Blood around some organs regulated by precapillary sphincters rings of smooth muscle around arterioles at capillary bed can regulate or stop blood flow to capillary bed. Example - close beds in skin to limit heat loss in cold environments.
Capillary Exchange
Heart provides sufficient pressure to pump against resistance of arterial tree and into capillaries
Every cell is within 100 μm of a capillary
Average capillary is 1 mm long, 8 μm diameter, slightly larger than a red blood cell

Capillaries have greatest cross-sectional area
Blood velocity decreases in capillary beds
Provides greater time for exchange of materials with tissues
Blood pressure is greatly reduced when blood enters veins
**Venules and Veins**
Veins and venules have thinner layer of smooth muscle than arteries.
Pressure one-tenth that of arteries can expand to hold greater quantities - most blood in body is in veins.

Venous pressure is insufficient to return blood to heart from feet - aided by contraction of skeletal muscles.
One-way venous valves direct flow toward heart.

Varicose veins - caused by blood pooling in veins when valves fail.
Circulatory system delivers by diffusion through capillary walls. Filtration driven by pressure of blood - supplies cells with nutrients. Most fluid returned by osmosis due to concentration of protein in blood. High capillary blood pressure causes production of too much interstitial fluid - “edema” - a swelling of tissues in extremities.

Edema commonly occurs in feet of pregnant women. Edema also results when plasma protein concentration is too low. May be caused by liver disease or protein malnutrition.
The lymphatic system recovers lost fluid and returns it to blood. Composed of lymphatic capillaries, lymphatic vessels, lymph nodes, and lymphatic organs like spleen and thymus. Fluid in tissues diffuses into blind-end lymph capillaries.

Lymph passes into larger vessels. Lymphatic vessels also contain one-way valves.
Major lymphatic ducts drain into veins on sides of neck
Lymph fluid movement assisted by movement of muscles
Some lymph vessels contract rhythmically
Lymph modified by phagocytic cells in lymph nodes and lymphatic organs
The Heart - has two pairs of valves

Atrioventricular (AV) valves lie between atria and ventricles
- on right side - tricuspid valve
- on left side - bicuspid or mitral valve

Semilunar valves lie between ventricles and main arteries
- right - pulmonary valve
- left - aortic valve

Right side sends blood to lungs
Left side sends blood to rest of body
How the Heart Is Stimulated to Contract
Caused by transmission of membrane depolarization triggered by **sinoatrial (SA) node** - the “pacemaker”
SA cells depolarize spontaneously with regular rhythm
depolarization passes from one cardiac muscle cell to another
cardiac cells are “electrically” coupled by gap junctions
Atria contract first - ventricular depolarization delayed by \(~ 0.1 \) sec
Separated by nonconductive connective tissue
Wave passes via **atrioventricular (AV) node**
Delay permits atria to empty before ventricles contract
Ventricles contract together - signal carried through atrioventricular bundle of fibers - “Bundle of His”

Signal transmitted by Purkinje fibers to bottom of ventricles stimulates ventricular cells to contract

Right and left ventricles contract almost simultaneously from bottom to top, emptying ventricles
ECG readings and contraction

P wave in ECG

QRS wave in ECG

ECG

R → 1 sec → R

T = Ventricular repolarization

QRS wave
Blood Pressure and the Baroreceptor Reflex

Arterial blood pressure depends on two factors
  - Cardiac output - how much ventricles pump
  - Resistance to flow

Increased blood pressure caused by
  - Increased heart rate or blood volume or resistance
    - Vasoconstriction - produces increased resistance to flow

Blood pressure will fall if
  - Heart rate slows or blood volume reduced or vasodilation

Baroreceptors are sensitive to changes in arterial blood pressure
  - Located in walls of aortic arch and carotid arteries
  - Connected to cardiovascular control center in medulla

When baroreceptors detect decrease in blood pressure
  - Stimulates an increased heart rate and vasoconstriction of vessels in skin and viscera
  - Raises blood pressure
Baroreceptors act to maintain blood flow to brain with rapid standing
Rapid standing changes venous pressure in lower body because this reduces pressure above the heart and increases volume of blood in lower body and reduces return of blood to heart and this results in reduced cardiac output
Low blood flow to brain can cause light-headedness or fainting
Reflex rapidly increases heart rate, constricts arterioles
Maintains normal blood pressure